

Assessment of Codes and Standards Applicable to a Hydrogen Production Plant Coupled to a Nuclear Reactor

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ABSTRACT

This is an assessment of codes and standards applicable to a hydrogen production plant to be coupled to a nuclear reactor. The result of the assessment is a list of codes and standards that are expected to be applicable to the plant during its design and construction.

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CONTENTS

ABSTRACT.....	iii
ACKNOWLEDGMENTS	v
ACRONYMS.....	ix
1. Introduction	1
2. Assessments.....	1
2.1 General Assessment.....	1
2.2 Nuclear Assessment.....	2
2.3 Hydrogen Specific Assessment	2
2.4 Regulatory Assessment	3
2.5 Results	3
3. References	4

TABLES

1. List of codes and standards applicable to a hydrogen production plant coupled to a nuclear reactor.....	5
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ACRONYMS

AASHTO	American Association of State Highway and Transportation Officials
ACI	American Concrete Institute
AIAA	American Institute of Aeronautics and Astronautics
AISC	American Institute of Steel Construction
AISI	American Iron and Steel Institute
ANL	Argonne National Laboratory
ANSI	American National Standards Institute
API	American Petroleum Institute
ARMA	Asphalt Roofing Manufacturers Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASD	Allowable Stress Design
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
ASME	American Society of Mechanical Engineers
AWS	American Welding Society
AWWA	American Waterworks Association
CAA	Clean Air Act / Air Programs
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CGA	Compressed Gas Association
CMAA	Crane Manufacturers Association of America
DCID	Director of Central Intelligence Directive
DM	Design Manual
DOE	Department of Energy

EJMA	Expansion Joint Manufacturers Association
ERDA	Energy Research and Development Administration
HEPA	High Efficiency Particulate Air
IAPMO	International Association of Plumbing and Mechanical Codes
ICBO	International Conference of Building Officials
ICEA	Insulated Cable Engineers Association
IDAPA	Idaho Administrative Procedures Act
IEEE	Institute of Electrical and Electronics Engineers
IES	Illuminating Engineering Society
IESNA	Illuminating Engineering Society of North America
IFC	International Fire Code
IMC	International Mechanical Code
INEEL	Idaho National Engineering and Environmental Laboratory
INL	Idaho National Laboratory
IPC	International Plumbing Code
ISA	A nonprofit automation and controls organization, http://www.isa.org .
ISDSI	Insulated Steel Door Systems Institute
ksi	Kips per Square Inch
LRFD	Load and Resistance Factor Design
LWP	Laboratory-wide Procedure
MBMA	Metal Building Manufacturers Association
MSS	Manufacturers Standardization Society
NAVFAC	Naval Facilities
NBS	National Bureau of Standards
NEMA	National Electrical Manufacturers Association
NEPA	National Environment Policy Act

NESC	National Electrical Safety Code
NFPA	National Fire Protection Agency
NISP	National Industrial Security Program
NISPOM	National Industrial Security Program Operating Manual
NRCA	National Roofing Contractors Association
OSHA	Occupational Safety and Health Administration
RCRA	Resource Conservation Recovery Act
SDI	Steel Deck Institute
SDI	Steel Door Institute
SEI	Structural Engineering Institute
SJI	Steel Joist Institute
SMACNA	Sheet Metal and Air Conditioning Contractors' National Association
SPRI	Single Ply Roofing Industry
TSCA	Toxic Substance Control Act
UBC	Uniform Building Code
UL	Underwriters Laboratory

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1. Introduction

This is an assessment of codes and standards applicable to a hydrogen production plant to be coupled to a nuclear reactor. Functional requirements for such a plant have already been described (Ward, 2006; Argonne National Laboratory - West, 2004). Relevant codes and standards, for both the nuclear and non-nuclear regulatory regimes applicable to permitting, design, and construction were considered. Requirements for operations were not considered given that significant development of the design will be needed before such consideration is meaningful.

2. Assessments

The assessment was made starting with the general and moving to the specific. There is a general set of codes and standards applicable to almost every facility designed and built in the United States. For instance, almost every facility will need provisions for its staff, and people need water in their day-to-day activities. Therefore, almost every facility will have piping designed and constructed to the provisions of the Uniform Plumbing Code. The specific effects of both the coupled nuclear reactor and the currently known characteristics of the production plant on the applicable codes and standards were then considered. Finally, permitting requirements were addressed.

The result of the assessment is a list of codes and standards that are expected to be applicable to the plant during its design and construction. The list is inclusive rather than exclusive. For instance, there are a number of piping codes that could be selected to govern the design and construction of piping. The majority of the commercial codes fall in the American Society of Mechanical Engineers (ASME) B31 code series (B31.3 being the most likely, but B31.1 could be selected, with B31.8 being the most likely code for a buried pipeline terminating at the plant). Other B31 codes may also be selected. This is indicated in the list with the entry “ASME B31 Series (B31.1, B31.3, and B31.8)”.

2.1 General Assessment

A list of codes and standards generally applicable to the design and construction of any Department of Energy (DOE) facility, including the subject hydrogen production plant, was taken from the Idaho National Laboratory's (INLs) documentation supporting its design activities (STD-116, 2005). The list was revised to reflect the current status of the codes and standards and constitutes the majority of the codes and standards listed in this report. The list includes a substantial number of national codes and standards, and some references to the United States Code, the Code of Federal Regulations, Department of Energy, and lab-specific (Sandia, INL, and INEEL) documents.

The DOE and lab specific documents that appear in the list will be directly applicable to the plant only if the work is done by a DOE Laboratory. Should the work be contracted to an outside entity, the requirements of these documents will be incorporated in the contract documents, and the DOE and Lab specific documents themselves will not be an explicit part of the codes and standards to which the plant will be built.

The list is contained in Table 1, included at the end of this report.

2.2 Nuclear Assessment

Federal law requires that the nuclear reactor associated with the hydrogen production plant be subjected to a Documented Safety Analysis (10 CFR 830, Subpart B). This process could have an effect on the codes and standards employed in the design of the hydrogen production plant ranging from minor to profound. An analysis has been undertaken to examine these potential impacts (Curtis Smith, Scott Beck, Bill Galyean, 2005). A number of design features have been identified that will minimize the effects of the nuclear requirements on the design of the hydrogen plant, provided that the loss of thermal efficiency resulting from imposing a blast-threat-reducing separation distance between reactor and production plant is acceptable. The design features discussed in the analysis include separation of hydrogen production from hydrogen storage areas, which may result in a design feature not commonly found at INL: a buried pipeline. The current code used for design and construction of a commercial buried hydrogen pipeline is ASME B31.8.

Should the separation distance yield unacceptable efficiencies, then changes in the hydrogen production plant design could include the addition of new systems, the replacement of commercial codes by their more strict nuclear counterparts, and the inclusion of codes specifying additional requirements for nuclear service. For example, the ASME B31 series (piping) and ASME Section VIII (pressure vessels) Codes could be replaced by their ASME Section III (Nuclear Components) counterparts. An example of additional nuclear requirements can be found in the qualification requirements for electrical equipment added by the Institute of Electrical and Electronics Engineers (IEEE) Standards 323, 344, 603, and 7-4.3.2 (IEEE Std 323-2003, IEEE Std 344-2004, and IEEE Std 603-1998). These codes represent imposition of additional design requirements and environmental and seismic testing requirements.

It is clear from this that an assessment of the codes and standards used in the design and construction of a hydrogen production plant cannot be undertaken without knowledge of the impact of a safety analysis of the associated nuclear reactor. Given that the results of the safety analysis are not available, the list presented here must be considered non-nuclear. This is true despite the fact that there are a small number of nuclear codes and standards in the list. These have been applied to the non-nuclear side because they have features attractive to the INL design community, and there are no equivalent documents on the non-nuclear side. For instance, AISC N690 is a nuclear code, but it offers structural provisions for stainless steel, which cannot be found on the commercial side, and hence is included in the list.

2.3 Hydrogen Specific Assessment

Two approaches were taken to assess the codes and standards applicable specifically to a hydrogen production plant, a web search and utilization of Applied Mechanics staff who actively participate in the Code writing activities of the ASME.

A web search was conducted using the proprietary IHS, Inc. web search capability^a provided by the INL Technical Library. Searches using the keyword “hydrogen” yielded a number of codes and standards from the American Petroleum Institute (API), the Compressed Gas Association (CGA), and the American Institute of Aeronautics and Astronautics (AIAA). These were added to the list.

^a <http://www.ihs.com/>

Applied Mechanics staff participation in ASME Code writing activities^b has provided a perspective on the current industry approach to hydrogen production facility design. Hydrogen piping is typically designed to ASME B31.3 and vessels to ASME VIII. Materials known to be resistant to hydrogen embrittlement are used in the higher-pressure applications where this effect is enhanced. Persistent leakage of hydrogen is a given, hence dedicated ventilation systems are included to minimize any resulting problems. Head spaces are eliminated or vented, since free hydrogen rises in air. These discussions, while not directly linkable to codes or standards, do provide useful design information.

2.4 Regulatory Assessment

The primary drivers of permitting activities were taken from the INL instructions for performing environmental planning, compliance, and protection (LWP-8000), augmented by the list of codes and standards developed by the general assessment. These include:

- 40 CFR 50-99 (Clean Air Act / Air Programs - CAA),
- 40 CFR 100-149 (Clean Water Act / Water Programs - CWA),
- 40 CFR 260-299 (Resource Conservation Recovery Act - RCRA),
- 40 CFR 300-349 (Comprehensive Environmental Response, Compensation, and Liability Act - CERCLA),
- 40 CFR 700-799 (Toxic Substance Control Act - TSCA), and
- 40 CFR 1500-1599 (National Environment Policy Act - NEPA).

Of these, CERCLA and TSCA deal exclusively with legacy issues that are not applicable to a new facility and are not included in the list.

There will be related requirements made by the state in which the facility is to be built. For Idaho, the requirements are in IDAPA 58 (Department of Environmental Quality).

2.5 Results

Table 1 on page 5 lists the codes and standards applicable to a hydrogen production plant identified during this assessment. The list is inclusive rather than exclusive. While most of the codes and standards eventually used in the permitting, design, and construction of a plant will be found in the list, it is not anticipated that all entries will be used. The list is sorted by standard number. Dates of issue were not included, since the usual practice is to adopt the most current version at the time of design.

^b ASME B31.12 for hydrogen piping and pipelines and revision of ASME VIII for vessels (the pressure range is being extended to 15 ksi, primarily to accommodate high-pressure hydrogen storage).

3. References

- 10 CFR 830, Subpart B, 2006, "Safety Basis Requirements," *Code of Federal Regulations*, Office of the Federal Register, January 2006.
- Argonne National Laboratory - West, 2004, Balance of Plant Requirements for a Nuclear Hydrogen Pilot Plant, Rev. 0, ANL W7500-003-ES-00, September 2004.
- Curtis Smith, Scott Beck, Bill Galyean, 2005, *An Engineering Analysis for Separation Requirements of a Hydrogen Production Plant and High-Temperature Nuclear Reactor*, INL/EXT-05-00137, Rev. 0, March 2005.
- IEEE Std 323-2003, "IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations," January 2004.
- IEEE Std 344-2004, "IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations," June 2005.
- IEEE Std 603-1998, "IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations," July 1998.
- IEEE Std 7-4.3.2-2003, "IEEE Standard Criteria for Digital Computers in Safety Systems of Nuclear Power Generating Stations," December 2003.
- LWP-8000, 2005, "Environmental Instructions for Facilities, Processes, Materials and Equipment," September 2005.
- STD-116, 2005, "INEEL Architectural Engineering Standards," Revision 31, March 8, 2005.
- Ward, Bradley, 2006, *Balance of Plant Requirements for a Nuclear Hydrogen Plant*, INL/EXT-06-11232, Rev. 1, April 2006.

Table 1. List of codes and standards applicable to a hydrogen production plant coupled to a nuclear reactor.	
Number	Title
10 CFR 435	Energy Conservation Performance Standards for New Buildings
29 CFR 1910	Occupational Safety and Health Standards (OSHA)
29 CFR 1926	Safety and Health Regulations for Construction
40 CFR 100-149	Clean Water Act / Water Programs (CWA)
40 CFR 1500-1599	National Environment Policy Act (NEPA)
40 CFR 260-299	Resource Conservation Recovery Act (RCRA)
40 CFR 50-99	Clean Air Act / Air Programs (CAA)
40 CFR 700-799	Toxic Substance Control Act (TSCA)
AASHTO	Standard Specifications for Highway Bridges
ACGIH	Industrial Ventilation Manual of Recommended Practice
AIAA G-109	Guide to Safety of Hydrogen and Hydrogen Systems (American Institute of Aeronautics and Astronautics)
AISC ASD	Specifications for Structural Steel Buildings, Allowable Stress Design, Plastic Design
AISC LRFD	Load and Resistance Factor Design Specification for Structural Steel Buildings
AISC N690	Nuclear Facilities: Steel Safety-Related Structures for Design, Fabrication and Erection
AISI	Specification for the Design of Cold-Formed Steel Structural Members
ANSI A117.1	Specifications for Making Buildings and Facilities Accessible to and Usable by Physically Handicapped People
ANSI A156 Series	Door and Window Hardware
ANSI A250.8	Recommended Specifications for Standard Steel Doors and Frames
ANSI B30.16	Overhead Hoists (Underhung)
ANSI C2	National Electrical Safety Code (NESEC)+B186
ANSI S3.5	Methods of Calculations of the Speech Intelligibility Index
ANSI/NB-23	National Board Inspection Code
API	American Petroleum Institute Guidelines
API RP (500, 505, 941)	Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Division 1 and Division 2
ARMA	Guide to Preparing Built-Up Roofing (BUR) Specifications, Recommended Performance Criteria for Roofing Membranes using Polymer Modified Bituminous Products
ASCE 7	Minimum Design Loads for Buildings and Other Structures
ASHRAE Standard 100	Energy Conservation in Existing Buildings
ASME (II, III, IVIII, IX)	ASME Boiler and Pressure Vessel Codes
ASME B1 Series	Threads
ASME B16 Series	Fittings, Flanges, Valves and Gaskets
ASME B30.2	Overhead and Gantry Cranes
ASME B31 Series (B31.1, B31.3, B31.8, B31.9)	ASME Piping Codes
ASME B36 Series	Pipe and Tubes
ASTM A795	Standard Specification for Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless Steel Pipe for Fire Protection Use
ASTM Series	Material and Product Standards

Table 1 (continued).	
Number	Title
AWS (D1.1)	American Welding Society Welding Codes
AWWA	American Water Works Association Standards
CGA G-4.1	Cleaning Equipment for Oxygen Service, 1996.
CGA G-5.5	Hydrogen Vent Systems, 1996.
CMAA 70	Specification for Electric Overhead Traveling Cranes
CMAA 74	Specification for Top Running and Under Running Single Girder Electric Overhead Traveling Cranes
DCID 1/21	Director of Central Intelligence Directive 07/94
DOD	Interim DOD Anti-Terrorism Force Protection Construction Standards Code
DOE 251.9	Security Requirements for Classified Automatic Data Processing
DOE 421.2A	Classified Automated Information System Security Program
DOE 5632.1C	Protection and Control of Safeguards and Security Interests
DOE CG-SS-3	DOE Classification Guide CG-SS-3
DOE G 420.1-1	Nonreactor Nuclear Safety Design and Explosives Safety Criteria
DOE G 420.1-2	Guide for the Mitigation of Natural Phenomena Hazards for DOE Nuclear Facilities and Nonnuclear Facilities
DOE G 420.1X	Implementation Guide for Nonreactor Nuclear Safety Design Criteria and Explosives Safety Criteria
DOE ID N 430.1A	Life Cycle Asset Management : ID Expectations
DOE M 200.1-1	Telecommunications Security Manual
DOE M 440.1-1	DOE Explosive Safety Manual
DOE M 471.2-1B, -1C	Classified Matter Protection and Control Manual
DOE M 471.2A	Technical Surveillance Countermeasures
DOE M 471.2B	Information Security Program
DOE M 5632.1C-1	Manual for Protection and Control of Safeguards and Security Interests
DOE N 2051	Unclassified Computer Security Program
DOE O 413.3	Project Management
DOE O 420.1	Facility Safety
DOE O 430.1	Life Cycle Asset Management
DOE O 430.2	In House Energy Management
DOE O 440.1	Worker Protection Management for DOE Federal and Contractor Employees
DOE O 473.1	Protection and Control of Safeguards and Security Interests
DOE/ID-10425	Storm Water Pollution Prevention Plan for Construction Activities - Generic Plan
DOE-HDBK-1062	DOE Fire Protection Handbook
DOE-STD-1020	Natural Phenomena Hazards Design and Evaluation Criteria for DOE Facilities
DOE-STD-1021	Natural Phenomena Hazards Performance Categorization Guidelines for Structures, Systems, and Components
DOE-STD-1031	Guide to Good Practices for Communications
DOE-STD-1042	Guide to Good Practices for Control Area Activities
DOE-STD-1066	Fire Protection Design Criteria
DOE-STD-1088	Fire Protection for Relocatable Structures
DOE-STD-1090	Hoisting and Rigging
DOE-STD-3003	Backup Power Sources for DOE Facilities
EJMA	Expansion Joint Manufacturers' Association Standards

Table 1 (continued).	
Number	Title
FM	Factory Mutual Approval Guide
FM (1-28, 1-28S, 1-54, 1-57, 3-2, 3-3, 3-7N, 3-10)	Factory Mutual Loss Prevention Data Sheets
IBC	International Building Code (IBC)
ICEA	ICEA Standards
Idaho Code, Title 1, Chapter 2	Idaho Water Quality Standards and Waste Water Treatment Requirements
IDAPA 37.03.09	Well Construction Standards Rules, State of Idaho Dept of Water Resources
IDAPA 58.01.08	Idaho Rules for Public Drinking Water Systems, State of Idaho Dept of Environmental Quality
IEEE 142	Grounding of Industrial and Commercial Power Systems
IEEE 242	Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems
IEEE 315, 315A	Graphic Symbols for Electrical and Electronics Diagrams
IEEE 399	Recommended Practice for Power Systems Analysis
IEEE 484	Recommended Practice for Design and Installation of Large Lead Storage Batteries for Generating Stations and Substations
IEEE 493	Recommended Practice for Design of Reliable Industrial and Commercial Power Systems
IEEE 576	Recommended Practice for Installation, Termination, and Testing of Insulated Power Cable as Used in the Petroleum and Chemical Industry
IEEE 80	Safety in AC Substation Grounding
IEEE C37 series	Circuit Breakers, Switchgear, Relays, Substations and Fuses
IES	IES Lighting Handbook
IFC	International Fire Code
IMC	IAPMO/ICBO International Mechanical Code
IPC	International Plumbing Code IAPMO
ISA	ISA Standards
ISA RP-60	Electrical Guide for Control Centers Recommended Practice
ISDSI 102	Installation Standard for Insulated Steel Door Systems
MBMA	Metal Buildings Systems Manual
MSS	Manufacturers Standardization Society Valve, Fitting and Hanger Standards
NAVFAC DM-4.9	Naval Facilities Engineering Command Design Manual "Energy Monitoring and Control Systems"
NBS 135	Life Cycle Cost Manual for Federal Energy Management Programs
NEMA	NEMA standards
NFPA	National Fire Protection Association (NFPA) Codes and Standards
NFPA 10	Portable Fire Extinguishers
NFPA 101	Life Safety Code
NFPA 101A	Alternative Approaches to Life Safety
NFPA 110	Emergency and Standby Power Systems
NFPA 12	Standard on Carbon Dioxide Extinguishing Systems
NFPA 13	Installation of Sprinkler Systems
NFPA 20	Installation of Centrifugal Fire Pumps
NFPA 22	Water Tanks for Private Fire Protection
NFPA 24	Installation of Private Fire Service Mains and Their Appurtenances
NFPA 30	Flammable and Combustible Liquids Code

Table 1 (continued).	
Number	Title
NFPA 31	Oil-Burning Equipment
NFPA 54/ANSI Z+A128223.1	National Fuel Gas Code
NFPA 58	Standard for the Storage and Handling of Liquefied Petroleum Gases
NFPA 70	National Electrical Code
NFPA 72	National Fire Alarm Code
NFPA 75	Standard for the Protection of Electronic Computer/Data Processing Equipment
NFPA 780	Standard for the Installation of Lighting Protection System
NFPA 79	Industrial Machinery
NFPA 80	Fire Doors and Windows
NFPA 90A	Installation of Air Conditioning and Ventilating Systems
NFPA 90B	Installation of Warm Air Heating and Air Conditioning Systems
NFPA Codes	Codes applicable to special occupancies or materials
NISP	National Industrial Security Program
NISPOM	National Industrial Security Program Operating Manual
NRCA	Roofing and Waterproofing Manual, Handbook of Accepted Roofing Knowledge
NSF	National Sanitation Foundation Listings
REA Bulletin 50-1	Standard T-805B
REA Bulletin 50-3	Standard D-804
REA Bulletin 50-6	Standard D-806
SAND 87-1926	Access Delay Technology Transfer Manual (UNCI)
SAND 99-2388	Interior Intrusion Detection, DOE-OSS (UNCI)
SAND 99-2389	Video Assessment, DOE-OSS UNCI
SAND 99-2390	Alarm Communications and Display DOE-OSS UNCI
SAND 99-2391	Exterior Intrusion Detection, DOE-OSS UNCI
SAND 99-2392	Protecting Security Communications DOE-OSS UNCI
SAND 99-2486	Explosives Protection, DOE-OSS UNCI
SDI	Design Manual for Composite Decks, Form Decks and Roof Decks
SDI 108	Selection and Usage Guide for Standard Steel Doors
SJI	Standard Specification for Open Web Steel Joists
SMACNA	Architectural Sheet Metal Manual
SPRI	Professional Guide to Specifications, Parts I-IV Wind Design.
TR 15916	Basic considerations for the safety of hydrogen systems
UBC	Uniform Building Code
UL	Product Directories of Underwriters' Laboratories, together with the periodic supplements (UL)
UL 1034	Burglary Resistant Electric Locking Mechanisms
UL 1076	Proprietary Burglar Alarm Units and Systems
UL 13	Power Limited Circuit Cable
UL 1610	Central Station Burglar Alarm Units
UL 1651	Optical Fiber Cable
UL 1778	Uninterruptible Power Supply Equipment
UL 294	Access Control system Units
UL 3044	Surveillance Closed Circuit Television Equipment
UL 365	Police Station Connected Burglar Alarm Units and Systems
UL 444	Communications Cables

Table 1 (continued).	
Number	Title
UL 452	Antenna Discharge Units
UL 497	Protectors for Paired Conductor Communications Circuits
UL 497B	Protectors for DATA Communications and Fire Alarms Circuits
UL 603	Power Supplies for use with Burglar Alarm Systems
UL 609	Local Burglar Alarm Units and Systems
UL 636	Holdup Alarm Units and Systems
UL 639	Intrusion Detection Units
UL 681	Installation and Classification of Burglar and Holdup Alarm Systems
UL 827	Central Station Alarm Service
UL 900	Test Performance of Air Filter Units
UL 96	Lightning Protection Components
UL 983	Surveillance Camera Units
	Recommended Standards for Wastewater Facilities, Great Lakes-Upper Mississippi River Board of State Public Health and Environmental Managers
	State of Idaho Transportation Dept, Division of Highways, Standard Specifications for Highway Construction
	U.S. DOE Security Container and Locking Device Guide
	Union Pacific Railroad, Technical Specifications for Industrial Tracks